Before The
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
Fostering Innovation and Investment in the Wireless Communications Market	)	GN Docket No. 09-157
A National Broadband Plan For Our Future	)	GN Docket No. 09-51

DECLARATION OF THOMAS W. HAZLETT

September 30, 2009

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I. QUALIFICATIONS AND BACKGROUND

1. My name is Thomas W. Hazlett. I am a Professor of Law & Economics and Director, Information Economy Project, at George Mason University. I received my Ph.D. in Economics from U.C.L.A, and I have previously held faculty appointments at the University of California at Davis, Columbia University, and the Wharton School. From 1991 to 1992, I served as Chief Economist of the Federal Communications Commission. I have published widely in academic and popular journals on the economics of telecommunications markets and, in particular, radio spectrum allocation.[1] I am also a Principal of

[1] *See, e.g.*, "Modularity in Mobile Networks: Is the iPhone iPhony?" Paper presented to the MSFT/GMU Conference on Law and Economics of Innovation (May 7, 2009); "A Welfare Analysis of Spectrum Allocation Policies," with Roberto E. Muñoz, 40 *RAND Journal on Economics* (Autumn 2009), 424-54; "Spectrum Allocation in Latin America: An Economic Analysis," with Roberto E. Muñoz, 21 *Information Economics and Policy* (June 2009); "Property Rights and the Value of Wireless Licenses," 51 *Journal of Law & Economics* (Aug. 2008), 563-97; "Optimal Abolition of FCC Allocation of Radio Spectrum," 22 *Journal of Economic Perspectives* (Winter 2008), 103-28; "The Spectrum-Allocation Debate: An Analysis," *IEEE Computing & Internet* (Sept./Oct. 2006), 52-58; "Advanced Wireless Technologies and Public Policy," with Matthew L. Spitzer, 79 *Southern California Law Review* (March 2006), 595-665; "The Social Value of TV Band Spectrum in European Countries," with Jüergen Müller and Roberto E. Muñoz, 8 *Info*, No. 2 (2006), 62-73; "Spectrum Tragedies," 22

Arlington Economics LLC. I have provided expert testimony to federal and state courts, regulatory agencies, committees of Congress, foreign governments, and international organizations.

2. AT&T requested that I address the issues raised in this FCC proceeding regarding wireless innovation, and this Declaration is submitted subsequent to that request. The analysis and opinions expressed in this Declaration are entirely my own.

II. PURPOSE AND SUMMARY OF DECLARATION

3. Wireless services are key drivers of the Information Economy, and radio spectrum is the lifeblood of wireless networks. As such, regulators face competing demands for spectrum from a wide range of potential users, all of whom desire bandwidth for their communications applications. The implication of this rivalry for access to additional spectrum is clear: frequency rights have opportunity costs.

4. Spectrum can be made available on either a licensed or unlicensed basis. With respect to licenses, policy makers began by relying on traditional, defined-use permits, such as those issued to broadcasters. In recent decades, the trend has favored the issuance of broad, flexible-use spectrum rights.[2] These liberal licenses have permitted competition and innovation to flourish, with licensees deploying bandwidth to the uses where it can create the largest social gains. Many economists urge regulators to authorize more such licenses.[3] Others argue, conversely, that the economy will most benefit from allowing additional access for

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Yale Journal on Regulation (Summer 2005), 242-74; "Liberalizing U.S. Radio Spectrum Allocation," 27 *Telecommunications Policy* (August 2003), 485-99; "The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's 'Big Joke': An Essay on Airwave Allocation Policy," 15 *Harvard Journal of Law & Technology* (Spring 2001), 335-469; "Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?" 41 *Journal of Law & Economics* (October 1998), 529-76; "The Cost of Rent Seeking: Evidence from the Cellular Telephone License Lotteries," with Robert J. Michaels, 39 *Southern Economic Journal* (January 1993), 425-35; "The Rationality of U.S. Regulation of the Broadcast Spectrum," 33 *Journal of Law & Economics,* (April 1990), 133-175.

[2] Evan Kwerel & John Williams, "A Proposal for a Rapid Transition to Market Allocation of Radio Spectrum," FCC Office of Strategic Planning & Analysis, Working Paper No. 38 (Nov. 15, 2002). What I have previously detailed as "exclusively-assigned, flexible-use spectrum licenses" are here referenced simply as "liberal licenses." See Hazlett & Spitzer (2006).

[3] Gregory L. Rosston & Thomas W. Hazlett, *Comments of 37 Concerned Economists,* Comment submitted to the Federal Communications Commission, WT Docket No. 00-230 (Feb. 7, 2001).

unlicensed devices, and some even argue that such unlicensed uses should have access to licensed frequency spaces already used by mobile phone subscribers. They cite the popular use of cordless phones, Wi-Fi radios, and other unlicensed devices as evidence that the license-exempt model can create additional social gains.

5. The regime in place today accommodates both types of deployments in varying degrees. The issue to address now is: How can additional gains be produced by incremental policies? With the lessons learned by observing how the regulation and use of spectrum produce economic value, we can improve and expand productivity-enhancing policies. Specifically, rules can be crafted that maximally support an evolutionary process of trial and error – testing new wireless technologies, discovering useful innovations, crafting disruptive business models, and then adopting those that produce net benefits while discarding those that generate net costs.

6. The purpose of this Declaration is to:

- describe the link between liberal licenses and value creation in the wireless sector;
- contrast licensed and unlicensed allocations, noting complementarities and substitutions;
- explain the efficiencies of voluntary spectrum sharing and the limitations of mandated spectrum sharing; and
- suggest specific policies to promote consumer welfare maximization.

7. These policy recommendations, driven by economic evidence revealing extremely large social values associated with liberal licenses at the relevant margin, focus on relaxing artificial spectrum constraints and encouraging voluntary spectrum sharing mechanisms.

III. WIRELESS VALUE CREATION

8. Liberal licenses have helped to create stunning economic value for consumers. Indeed, the development of mobile networks over the past quarter-century has triggered a revolution in communications. Both in the U.S. and globally – where some 4.6 billion persons now carry cell phones – the use of wireless technology has changed lives and lifted economies. The mobile handset is now an iconic innovation of the Information Age.

9. A pronounced regulatory shift has been a crucial element in the development of these valuable networks: U.S. regulators moved from traditional licenses that imposed technology, service, and business model mandates on licensees, to liberal licenses delegating such choices to competitive markets. These extend flexibility to licensees creating complex networks, configuring service menus, and experimenting with customized business models. By one key metric – capital outlays for network development – resulting investment has been robust: over $240 billion has been sunk in U.S. mobile networks,[4] far outstripping efforts elsewhere in the wireless sector.

10. Consumers and the economy have gained immensely. U.S. mobile phone networks generate annual expenditures of some $150 billion in service revenues and $20 billion in network investment (base stations and technology, excluding license costs). In addition, some $11.3 billion was spent on cell phones in 2008, along with another $11.4 billion on smart phones.[5] Conservative estimates of consumer surplus generated by U.S. mobile networks exceed $150 billion per year.[6]

11. Importantly, allocating additional bandwidth to these networks would result in very substantial marginal gains. By examining the performance of 28 countries' mobile voice markets with operating data from 1999-2003, Roberto Muñoz and I show that another 30 MHz of CMRS spectrum in the U.S. would have, in 2003 alone, generated about $10 billion in incremental economic benefits.

12. U.S. carriers have been constrained by parsimonious bandwidth allocations – only about 194 MHz were yet in use by carriers in Dec. 2008,[7] about 100 MHz below other countries of similar income levels.[8] Fortunately, additional bandwidth has been made available (or soon will be, as band-clearing operations progress) as per the AWS (Sept. 2006) and 700 MHz (March 2008) license

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[4] This excludes expenditures for licenses, as well as for handsets or other devices. CTIA, "Wireless Industry Indices; Semi-Annual Data Survey," Year-End 2008 (May 2009), 136-138.

[5] Consumer Electronics Association (CEA) database (2008).

[6] These estimates are for voice services, e.g., excluding wireless data. Jerry A. Hausman, "Cellular, 3G, Broadband and WiFi," in R. Cooper and G. Madden, *Frontiers of Broadband, Electronic and Mobile Commerce* (2004), 9-25.

[7] Rysavy Research, "Mobile Broadband Spectrum Demand," (Dec. 2008), 23; http://files.ctia.org/pdf/FINAL_Rysavy_Spectrum_Demand_%5B1%5D.pdf.

[8] Thomas W. Hazlett & Roberto E. Muñoz, "What Really Matters in Spectrum Allocation Design," AEI-Brookings Joint Center for Regulatory Studies Working Paper 04-16 (Aug. 2004), 41.

auctions. This bandwidth is helping fuel large-scale network upgrades, increasing speed and performance of wireless devices, and propelling new waves of innovation. While the FCC has erroneously called liberal licenses "exclusive use" spectrum,[9] it is by far the most intensely utilized spectrum from an economic perspective. This is because the value of the spectrum depends critically on the complementary network infrastructure deployed; the most ambitious of these investments are made possible by the incentives conveyed via liberal licenses.

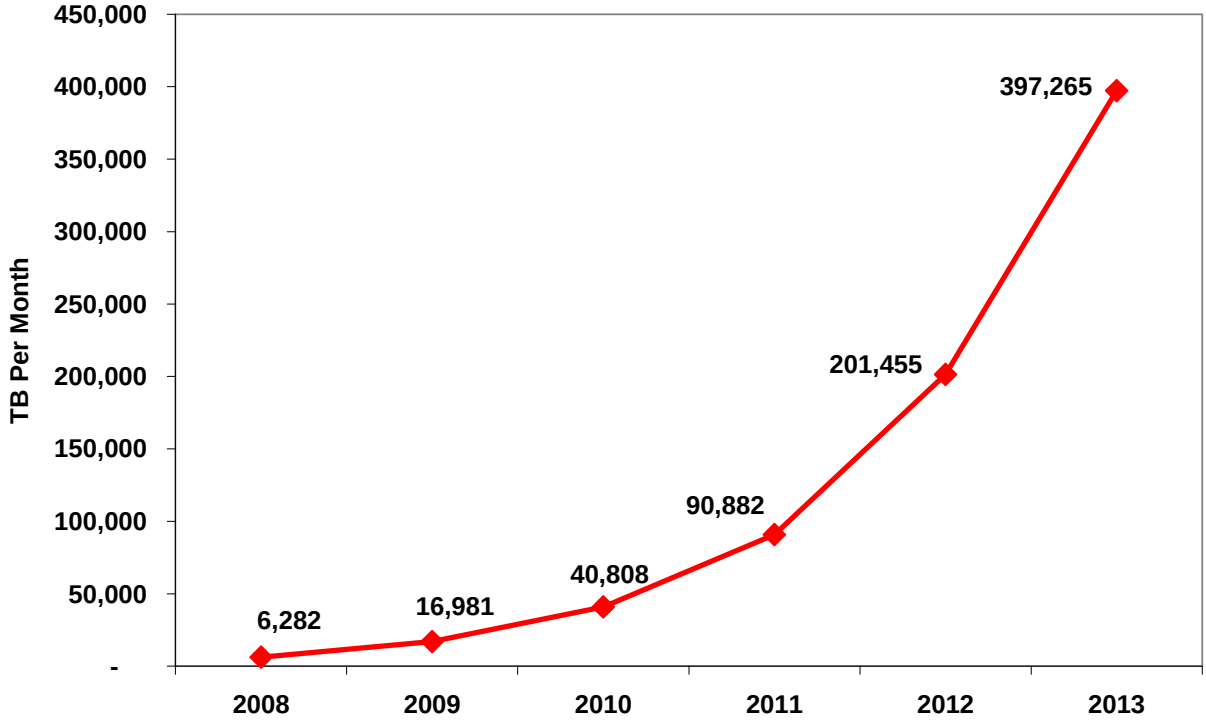
13. A recent illustration was when T-Mobile, starved for spectrum and unable to offer its customers high-speed data services, purchased nationwide bandwidth for $4.2 billion in the Sept. 2006 AWS auction. It immediately announced a $2.7 billion network upgrade to 3G.[10] The carrier became the fourth national 3G network vying for consumers and for applications – including the Google gPhone, a mobile applications platform offered by T-Mobile (with the G1) since their 3G launch in 2008.[11]

[9] This term is taken from the FCC's Spectrum Policy Task Force Report (Nov. 15, 2002). The confusion that the term reflects is discussed in Hazlett & Spitzer (2006), 621-22.

[10] "T-Mobile Calls AWS Auction Huge Success, Allowing 3G Rollout," *Communications Daily* (Oct. 10, 2006).

[11] "T-Mobile Launches the Highly Anticipated G1," T-Mobile Press Release (Oct. 22, 2008). It should be noted that innovators using liberal licenses have contributed new products besides mobile voice and data. Using 700 MHz licenses purchased at FCC auctions, Qualcomm's MediaFlo offers mobile video using advanced technology to deliver more than 20 channels in the same radio space that used to accommodate just one analog TV station (Channel 55). The service, marketed by wireless carriers AT&T and Verizon, may or may not prove a hit with customers. But the risk-taking needed to bring a new product to market (Qualcomm has reportedly invested about $1 billion in the deployment) reveals the entrepreneurial dividends yielded by liberal licenses, which protect spectrum-enhancing investments from appropriation. See Olga Kharif, "Qualcomm's Crystal Ball," *Business Week Online* (Jan. 18, 2007); http://www.businessweek.com/technology/content/jan2007/tc20070118_773450.htm.

FIG. 1. NORTH AMERICAN MOBILE DATA TRAFFIC, 2008-13[12]



14. Mobile markets are witnessing explosive growth in data traffic, and forecast to experience even higher demands. See Figure 1. This reflects a dramatic shift in network usage, as the voice services that mobile operators were formed to supply are now being eclipsed by texting, email, web browsing, GPS, audio and video streaming, and various other applications, some of which substitute for voice calls and others that complement them.

15. This dynamic change is endogenous: the creation of networks, services and applications – which critically rely on the spectrum rights conveyed in liberal licenses – are driving the expansion of the sector from within. The observed bandwidth migration from voice to data and video is market-driven. No U.S. government policy has mandated that wireless operators shift their focus, nor have the licenses issued distinguished between types of traffic.[13] Rather, a liberal

[12] Cisco, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," White Paper (Jan. 29, 2009), 6; http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf.

[13] Of course, some countries have distinguished between the services it is permissible for mobile operators to offer – a distinction found in the 1G, 2G, 3G licensing path. The U.S. CMRS policy adopted in 1993 eliminated such distinctions. To block the spectrum allocated to 1G or 2G licenses from hosting "3G" data services imposes needless, inefficient restrictions on networks.

environment has given operators the flexibility to search for, and exploit, emerging opportunities.

16. Countless applications have been creatively designed and innovatively deployed on the developing high-speed wireless data platforms. These include a number of burgeoning sub-markets, and I will discuss just two of those here: smart phones and M2M (machine to machine) radio devices.[14] The development of each of these sets of services demonstrates how flexible use spectrum rights support efficient allocation of radio spectrum.

17. *Smart Phone Platforms*. Every industry evolves, and as it does so the vertical structure of firms often changes. In the early days of the computer industry, for example, products were highly packaged. A computer made by IBM consisted of electronics manufactured by IBM, an operating system written by IBM, and applications custom-made for the customer by IBM programmers. Over time, this vertically integrated structure dissolved. Modularity increased to the degree that chips (and other electronic components), operating systems, and applications could all be efficiently produced by independent firms – and then assembled by another, and sold to the customer by yet another. This evolution to modularity has been seen in many other markets, although sometimes the migration is in the opposite direction – towards increasing integration. Most often, there are multiple structural changes occurring at once, some feeding more modularity and some bolstering integration.[15]

18. The strong general trend in U.S. wireless markets is today towards the creation of independent, non-carrier application platforms clustered around mobile operating systems and handset hardware. Smart phone "ecosystems" such as RIM Blackberry, Apple iPhone, Google gPhone, and webOS (Palm Pre) – among many others – typify the trend. These spontaneous product innovations demonstrate how liberal licenses support evolving spectrum markets.

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[14] There are other ways in which carriers supply spectrum inputs for other firms. MVNOs (mobile virtual network operators) purchase wireless connectivity for their retail customers; TracFone, which serves 11 million customers, is an example. Another wholesale market exists in roaming agreements, where operators can obtain a larger "network footprint" by arranging for their customers to seamlessly access spectrum allocated to other carriers' licenses. The Jitterbug phone has pieced such agreements together without any substantial "home network," creating a national network (similar to an MVNO).

[15] See, generally, Carliss Baldwin, "Modularity, Transactions, and the Boundary of Firms: A Synthesis," Harvard Business School Working Paper 08-013 (2007).

19. Using diverse strategies, non-carrier technology firms create their own unique service environments. Although they do not hold spectrum licenses or build their own wireless network assets, these suppliers enter into *ad hoc* contracts with holders of liberal licenses to gain access to spectrum. These firms then build devices that will provide the consumer experience contemplated in the contractual agreement. Consumers then purchase these devices as "plug 'n play" devices.

20. Competing platforms develop rival service environments. Apple's App Store – opened in 2008 – now features some 85,000 applications to ride on the iPhone (and other Apple devices), and has seen over 2 billion downloads.[16] Apple benefits indirectly from the App Store, which drives demand for iPhones, and directly, as Apple takes 30% of application revenues. Apple's foray, itself a reaction to the product space pioneered by the RIM Blackberry, has now triggered rivals of its own. This vividly illustrates how wireless carriers can build businesses with liberal licenses that in turn generate spectrum sharing across consumers, vendors, application developers, and investors in wireless network facilities.[17]

21. The development of such platforms enables thousands of "wireless applications" to access the mass-market, produced by entrepreneurs who (a) own no wireless assets or infrastructure; (b) have strong economic incentives (including billing services provided by the carrier or platform creator) to offer compelling content; and (c) operate in a highly competitive environment. The fact that small-scale software developers are well-equipped to enter this market, and have done so *en masse*, reflects efficiencies of the underlying regime of liberal licenses. The transaction costs incurred to gain access to exclusively held spectrum rights pale in comparison with the benefits generated. Gains from trade lead economic agents to widely engage in value-creating alliances.

22. *M2M.* The development of machine-to-machine networks has also been facilitated by the availability of flexible-use spectrum rights held by licensees. Such services use radio communications that occur on an automated basis, as when a truck fleet is monitored in real time by telematic devices. In 2008, some 88 million such devices were in use in the U.S., and CMRS carriers expected

[16] "Apple's App Store Downloads Top Two Billion in First Year," Apple Press Release (Sept. 28, 2009); http://www.apple.com/pr/library/2009/09/28appstore.html.
[17] See Hazlett (2009).

$2.5 billion to $3 billion in revenues from the use of these devices on their networks.[18]

23. Such services include OnStar, an emergency radio service sold by General Motors for use in trucks and automobiles, alarm systems, remote monitoring of manufacturing equipment, product and vehicle tracking, environmental monitoring, telemedicine applications for use in ambulances that provide remote diagnostics, and much more. When an Amazon Kindle customer buys a digital product from Amazon, the product is downloaded via "Whispernet" courtesy of the Sprint mobile network in a transaction seamless to the end user. (Sony's competing e-Reader operates similarly.) Machine-to-machine consumer and industrial applications in fields as diverse as navigation, smart electricity grids, gaming, and security cameras are under development or have been deployed. The possibilities – just in the health care industry – are limitless.

24. Here spectrum inputs provided to the wireless markets are performing just as theory predicted: with liberal property rights, market transactions are making bandwidth available where customers most desire to pay for it. Device and application innovators are drawn into a virtuous circle with wireless license holders; cool new apps increase the value of the network, while the expansion of subscribers and network infrastructure – including bandwidth – increase the scope for features and functionality of the applications. Economic rewards anticipated in future periods encourage investment both at the "edge" and in the "core," resulting in extremely valuable new services to the public.

IV. LIBERAL LICENSES AND UNLICENSED BANDS AS SUBSTITUTES

25. Short-range applications such as cordless phones, remote controls, baby monitors, medical and scientific devices and Wi-Fi, provide valuable services, and the investments undertaken to develop these uses will be protected in any policy going forward. The interesting question is how to create additional spectrum allocations that will lead to the networks and services most valued by consumers. On this margin the non-exclusive use rights of unlicensed spectrum allocations will generally prove inefficient when liberal licenses are the excluded option.

[18] John W. Mayo & Scott Wallsten, "Enabling Efficient Wireless Communications: The Role of Secondary Spectrum Markets," paper delivered to the Georgetown-U.C. Berkeley Conference on Wireless Technologies: Enabling Innovation and Economic Growth (April 17, 2009).

26. Unlicensed allocations permit firms or individuals to use spectrum inputs set aside for them by government regulators. The key innovation in the regulation of such bandwidth occurred in 1985 (and with a follow-up FCC ruling in 1989), with the decision to authorize a whole class of new spread spectrum radios.[19] This paved the way for both cordless phones and Wi-Fi devices in the years that followed.[20] Such short-range applications either need no network connectivity (*e.g.*, remote controls, baby monitors) or serve to complement wide area networks (WANs), including wireless WANs (WWANs). In either event, the fact that usage rights in such bands are non-exclusive pre-empts marketplace transactions that would reveal the value of additional unlicensed spectrum access rights relative to competing options.

27. Therefore, government regulators can only guess at the utility that will be created by the allocation of unlicensed spectrum. The fact that usage of existing unlicensed bandwidth has grown does not guarantee that new, additional bandwidth would produce similar results or that the value derived would exceed the opportunity costs of the set-aside. This is seen in several recent unlicensed allocations that have generated little additional economic activity while blocking valuable social opportunities. The 30 MHz allocated to unlicensed personal communications services (U-PCS) in the early to mid-1990s is one example. While very lightly used, the costs of the allocation have proven very high – services provided with licensed PCS spectrum, identical in its technical properties to U-PCS airwaves, generate billions of dollars in annual consumer surplus (as noted above). Quarantining the U-PCS spectrum in unlicensed bands has prevented the deployment of bandwidth where consumers most desire to use it.

28. Similarly, the FCC set aside 50 MHz of prime spectrum for non-exclusive access in the 3650-3700 MHz band in 2004-05.[21] By mandating non-exclusive use rights,[22] the FCC is almost certainly excluding more valuable

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[19] Michael J. Marcus, "Wi-Fi and Bluetooth: the path from Carter and Reagan-era faith in deregulation to widespread products impacting our world,",11 *Info*, No. 5 (2009), 19-35.

[20] Kevin J. Negus & Al Petrick, "History of wireless local area networks (WLANs) in the unlicensed bands," 11 *Info*, No. 5 (2009), 36-56.

[21] Federal Communications Commission, *In the Matter of Wireless Operations in the 3650-3700 MHz Band: Report and Order*, ET Docket No. 04-151 (Rel. March 16, 2005).

[22] Service providers are required to register in the FCC database, but there are no exclusive rights and entry is unlimited. This is, therefore, an unlicensed regime in which the protocol mandated by regulators involves locational information to help mitigate conflicts.

services.[23] Globally, the 3.5 GHz band is the most popular frequency location for WiMax, a leading next-generation wireless broadband technology, accounting for 37% of all consumer equipment shipped.[24] Those investments are generally not taking place in the U.S. As noted below, U.S. WiMax investment is instead concentrated in *licensed* spectrum at 2.5 GHz.

29. The argument has been made for many years that unlicensed spectrum would supply a competitive substitute for "last mile" voice or data services, but experience has proven otherwise. By mid-2008, FCC data indicate that there were nearly 133 million high-speed Internet connections. See Table 1. Of these about 72 million were delivered via wireline carriers, and 59 million by mobile operators using liberal (CMRS) licenses. A small component was recorded for "fixed wireless" subscribers – just over 800,000. This category accounts for Internet access supplied by wireless Internet service providers (WISPs). Despite the opportunity to use ISM bands, 3650 MHz, or other unlicensed allocations (which, some argue, reduce up-front costs by eliminating the need to purchase spectrum), WISPs have attracted a relatively small number of broadband subscribers.[25]

30. Moreover, the WISP subscriber count is itself dominated by Clearwire, which accounts for about half the total.[26] Clearwire's initial strategy was to use unlicensed airwaves to provide Internet access service, but it abandoned that path in favor of licensed bandwidth. Clearwire then aggregated spectrum rights nationwide by buying 2.5 GHz Broadband Radio Service (BRS) licenses and by contracting with non-profit institutions that own Educational Broadcasting Service (EBS) licenses. This has already resulted in advanced WiMAX services now being delivered to over 400,000 U.S. subscribers, and has triggered competitive reactions from mobile carriers:

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[23] These are discussed in Jerry Brito, "The Spectrum Commons in Theory and Practice," *Stanford Technology Law Review* (2007), 1-22; http://stlr.stanford.edu/pdf/brito-commons.pdf.

[24] Bilel Bouraoui & Adlane Fellah, "WiMAX & Broadband Wireless Access Equipment Market Analysis, Trends and Forecasts, 2009-2014," Maravedis (June 2009); https://www1.vtrenz.net/imarkownerfiles/ownerassets/328/Brochure_BWA_Equipment_Shipments_Report_June2009.pdf. The 3.65 GHz band would accommodate radios developed for the adjacent 3.5 GHz band with minor (and inexpensive) modification.

[25] Not all high-speed wireless connections are considered broadband connections. These distinctions are not directly relevant to this analysis.

[26] In June 2008, the FCC counted 808,000 "fixed wireless" subscribers, while Clearwire reported 461,000 total subscribers, of which about 412,000, were in the. U.S. Company Press Release (Aug. 7, 2008); http://newsroom.clearwire.com/phoenix.zhtml?c=214419&p=irol-newsArticle_Print&ID=1185181&highlight=.

> **Competition for mobile broadband deployments**: Despite pressures to minimize CAPEX spend, the top US carriers will continue to push forward on 3G/3.9G deployments in 2009. The US is likely to be one of the first countries with LTE deployments, using the already auctioned 700 MHz and AWS bands. Competition with WiMAX, as well as between the top two carriers, will drive LTE deployments. Verizon Wireless has indicated LTE will be launched in at least one market by late 2009.[27]

31. That Clearwire now accounts for as many "fixed wireless" subscribers as all other WISPs combined may be less important than the fact that the company has enlisted over $3 billion in capital from investors – including Intel, Motorola, Google, and equity purchasers in the company's 2007 IPO – to build out its network facilities with licensed bandwidth. Nowhere are investors marshalling similar resources to improve wireless services in unlicensed spaces.

[27] Strategy Analytics, "U.S. Wireless Market Outlook: 2009 Key Trends," (Jan. 2009), 15 (emphasis original).

TABLE 1. U.S. WIRELESS HIGH-SPEED INTERNET SUBSCRIBERS[28]

Technology	2004		2005		2006		2007		2008
	Jun	**Dec**	**Jun**	**Dec**	**Jun**	**Dec**	**Jun**	**Dec**	**Jun**
ADSL	11,398,199	13,817,280	16,316,309	19,515,483	22,583,548	25,412,509	27,792,800	29,449,166	29,963,968
SDSL and Traditional Wireline	1,407,121	1,468,566	898,468	741,904	809,209	889,266	941,685	898,363	939,692
SDSL			411,731	368,782	337,412	344,759	319,991	293,421	274,582
Traditional Wireline			486,737	373,122	471,797	544,507	621,694	604,942	665,110
Cable Modem	18,592,636	21,357,400	24,017,442	26,558,206	29,173,449	31,981,705	34,404,368	36,506,972	38,190,355
Fiber	130,928	159,653	315,651	298,052	547,082	893,995	1,280,994	1,848,565	2,346,328
Satellite and Wireless	421,690	549,621	965,068	3,812,029	11,873,157	23,343,199	36,560,869	52,514,007	61,368,444
Satellite			376,837	426,928	495,365	571,980	668,803	791,142	869,450
Fixed Wireless			208,695	257,431	361,272	483,470	586,813	706,522	808,375
Mobile Wireless			379,536	3,127,670	11,016,520	22,287,749	35,305,253	51,016,313	59,690,619
Power Line and Other			4,872	4,571	5,208	4,776	5,420	5,274	5,197
Total Lines	31,950,574	37,352,520	42,517,810	50,930,245	64,991,653	82,525,450	100,986,136	121,222,374	132,813,984

[28] Source: Federal Communications Commission, "High-Speed Services for Internet Access: Status as of June 2008," (July 2009); http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-292191A1.pdf.; December 2004 data obtained from the Federal Communications Commission, "High-Speed Services for Internet Access: Status as of December 31, 2007," (Jan. 2009); http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-287962A1.pdf.

32. Were unlicensed bands to become effective substitutes for licensed spectrum, the economic advantages afforded by liberal licenses would decline or evaporate.[29] Service providers would economize if they could effectively use zero-priced spectrum inputs to supply the most valuable wireless services. This substitution would reduce demand for licenses, *ceteris paribus*. This is a testable implication of the hypothesis that license-exempt bands are economically eclipsing licensed spectrum.[30]

33. Thus far, the hypothesis is rejected by the facts. Exclusive spectrum rights continue to be extremely useful, to sell for significant sums in both primary and secondary markets, and to host bountiful economic activity that could not be so efficiently supplied were such rights not in existence. Despite the opportunity to access unlicensed bands and to deploy 802.11 spread spectrum radios, U.S. firms remain eager to bid in auctions and to then invest heavily in network infrastructure to enhance the frequency spaces secured. This is true for large incumbent networks like AT&T and Verizon, for smaller incumbent networks like T-Mobile, or entrants such as Clearwire. In fact, Figure 2, displaying the prices obtained by the FCC for CMRS licenses in auctions held 1995-2008, suggests that prices may be *increasing* despite the larger allocations of liberal licenses available to the market. Neither the introduction of Wi-Fi devices nor major new unlicensed allocations, such as for ultra-wideband (2002), appear to have dissipated the premium placed on exclusively assigned spectrum rights.[31]

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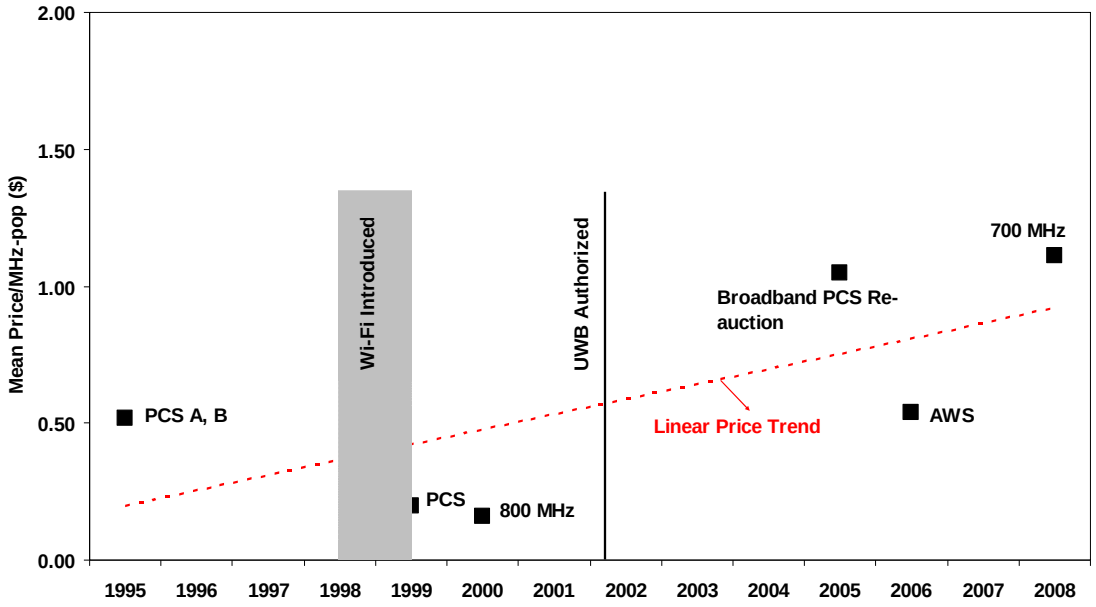
[29] This leaves unanswered the policy question as to whether greater social productivity could be enjoyed with additional allotments under one regime or the other.

[30] The argument that services are efficiently migrating to unlicensed spectrum has led to the prediction that: "The spectrum portfolios of large cellular phone companies will certainly be devalued." Gregory Staple & Kevin Werbach, "The End of Spectrum Scarcity," *IEEE Spectrum* (March 2004); http://www.spectrum.ieee.org/mar04/3811.

[31] Clearly, wireless license prices are influenced by several other factors, including overall stock market values, the location of the bandwidth allocated licenses, and competitive pressures among licensees. The latter suggests that the more licensed bandwidth, and the fewer the regulatory restrictions, the lower license prices. See Hazlett (2008).

FIG. 2. CMRS LICENSE PRICES IN FCC AUCTIONS, 1995-2008[32]



34. There is no serious question that exclusive spectrum rights are key to encouraging investment in communications networks that form the heart of the sector and which generate the economic activity on which all users and service providers depend. Examining global data on equipment sales, both for consumer devices and network capital, the dominance of wide area wireless networks (using licensed spectrum) is apparent. Over $200 billion is annually invested, as opposed to under $4 billion in wireless local area networks, which include Wi-Fi. See Table 2. These data exclude equipment purchases for wired communications (owned spectrum) and all service revenues, and thus vastly under-count the economic activity generated by exclusively assigned spectrum inputs.

[32] Mean auction prices taken from Jeremy Bulow, Jonathan Levin & Paul Milgrom, "Winning Play in Spectrum Auctions," NBER Working Paper No. 14765 (March 2009), 28. PCS A, B mean taken from Congressional Budget Office, "Where Do We Go From Here? The FCC Auctions and the Future of Radio Spectrum Management" (April 1997), Table 1. CMRS auctions that involved uncollectible bids are excluded from the analysis.

TABLE 2. GLOBAL EXPENDITURE ON TELECOM EQUIPMENT, 2000-2005						
Category	(millions of constant U.S. dollars)					
	2001	2002	2003	2004	2005*	2006*
Mobile Carrier Capex	84,883	73,560	69,408	81,474	92,175	97,435
Mobile Handsets	95,859	95,513	105,095	112,304	123,773	128,790
Total Mobile Investment	180,742	169,073	174,503	193,778	215,948	226,225
Handsets Sold (mil.)	432	427	508	683	810	896
Mobile Subs (mil.)	947	1,141	1,384	1,725	2,067	2,396
Wireline Capex	154,396	99,668	87,426	87,782	94,910	98,323
WLAN	1,405	1,696	2,194	2,802	3,881	3,783
SO/HO/Home	533	898	1,310	1,591	1,887	2,211
Enterprise	872	798	884	1,211	1,994	1,572

Source: Morgan Stanley, "Q2 2005 Global Technology Databook," Global Equity Research (June 1, 2005), 18, 20; Morgan Stanley, "Q1 2006 Global Technology Databook," Global Equity Research (March 3, 2006), 22, 24. *estimated.

35. It has long been known that traditional spectrum allocation leaves much spectrum capacity wasted.[33] Robust economic activity has been observed on some bands, with adjacent spectrum lying fallow.[34] Analysts have sought to investigate how much spectrum is actually used, contrasting utilization rates band by band to reveal differences associated with alternative regimes. A series of studies by Shared Spectrum uses technical emission measurements to generate such data for the prime spectrum under 3 GHz.[35] The levels were then categorized as occupancy rates equal to the proportion of the (theoretical) capacity of the frequency space being utilized. The main reported finding was that much spectrum was being wasted according to these technical measurements.[36]

[33] This was the central premise in R. H. Coase, "The Federal Communications Commission," 2 *Journal of Law & Economics* (1959), 1-40. See also, R. H. Coase, William Meckling, and Jora Minasian, "Problems of Radio Frequency Allocation," Rand Corporation DRU-1219-RC (Sept. 1995).

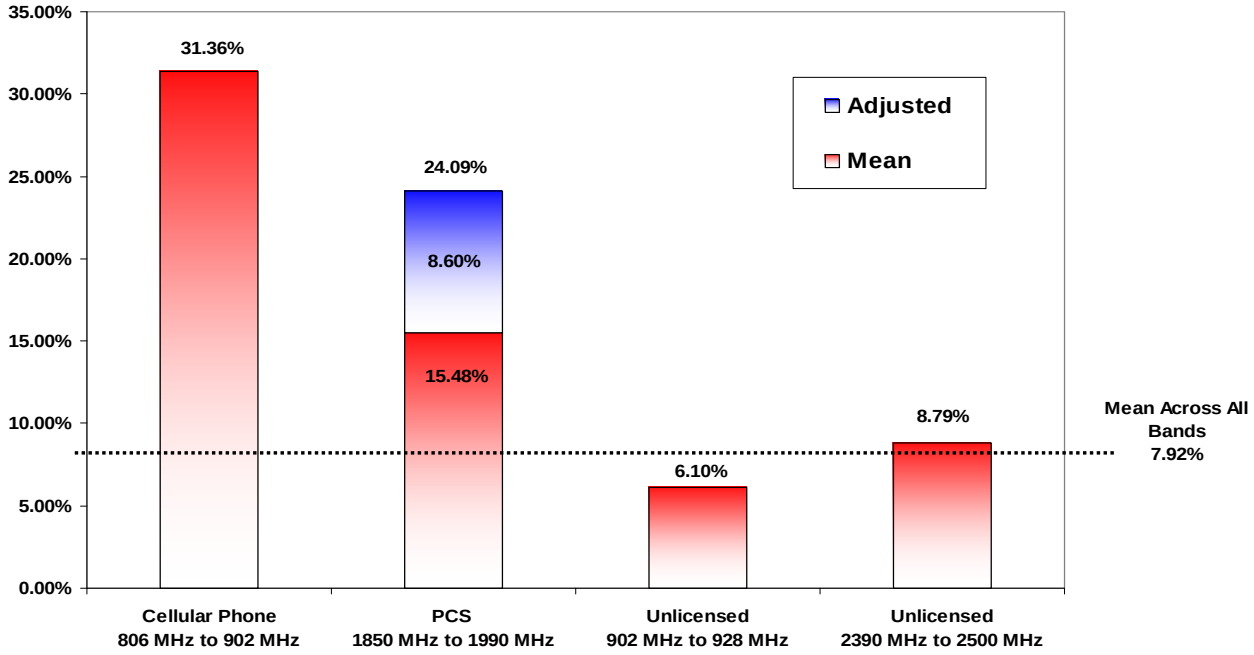
[34] See, e.g., Michael Heller, *The Gridlock Economy* (2008), Chapter 4.

[35] Shared Spectrum Occupancy Measurements; http://www.sharedspectrum.com/measurements/.

[36] Michael Calabrese, "The End of Spectrum Scarcity: Building the TV Bands Database to Access Unused Public Airwaves," New America Foundation Working Paper #25 (June 2009), 3; http://www.newamerica.net/files/Calabrese_WorkingPaper25_EndSpectrumScarcity.pdf.

36. The findings reveal more. First, unlicensed bands at 900 MHz and 2.4 GHz are occupied at only about the average rate, and far *less* than the spectrum allocated to liberal licenses covering the cellular band (800 MHz) and the PCS band (1850-1990 MHz). Shared Spectrum's general results, measuring six different locations, are dispayed in Fig. 3. The licensed PCS band is adjusted for the fact that licensed PCS frequencies constituted just 90 MHz of the 140 MHz studied (reported occupancy for the band is multiplied by [140/90]).[37] Taking the unweighted mean across all bands and all six locations, the average "occupancy" is estimated to equal 7.92%. The unweighted means of the cellular and PCS bands were measured at three to four times this level; the average of the two unlicensed bands, in contrast, is below the aggregate average (i.e., 7.92%).[38]

FIG. 3. OCCUPANCY RATES IN LICENSED V. UNLICENSED SPECTRUM[39]



[37] The PCS band is defined in the study as 1850-1990 MHz. When the measurements were taken in 2004, 20 MHz of U-PCS spectrum (1970-1990) was allocated to unlicensed and was virtually entirely vacant, while the 30 MHz allocated to the PCS C Block was also largely vacant (due to legal problems with FCC bidding credit subsidies).

[38] Emission levels, while revealing something about wireless activities, do not map directly to *economic* utilization. "Based on the occupancy measures, the conclusion can not be drawn that spectrum allocations are under utilized or inefficient." John T. MacDonald, "A Survey of Spectrum Utilization in Chicago" (March 7, 2007), 10-11; http://www.ece.iit.edu/~wemi/publications/spectrum.pdf.

[39] Data from Shared Spectrum Occupancy Measurement Reports; http://www.sharedspectrum.com/measurements/.

37. The perceived under-utilization stems in part from the fact that the rights that govern the unlicensed bands are non-exclusive. Much potential airwave space is left idle because higher powered devices, more economical devices, or more extensive network infrastructure are excluded. In addition, many efficient contracts, such as those in which PCS, AWS, or 700 MHz licensees have paid incumbent radio users to accept interference (or, equivalently, to relocate their operations) enable licensees to pack bands with newer technologies that more intensively utilize frequency space. Such cooperative efforts are generally unavailable to users of unlicensed bands.

38. These technical measurements understate the relative economic importance of liberal licenses. That is because the traffic on CMRS networks is relatively valuable, as per the revealed preference to supply it to customers paying access prices set by carriers. In unlicensed bands, that is not the case. Emissions that generate considerable "occupancy" may not generate much economic benefit. Because opportunities that are blocked do not cost the party engaging in the transmission (beyond electricity inputs), they must be baked into standards set by regulators or they tend to be ignored. Not so with liberal licenses, where licensees relentlessly attempt to divert bandwidth to the most pressing demands.

V. EFFICIENT SPECTRUM SHARING

39. The most intensively shared spectrum is found not in unlicensed bands but in the CMRS bands, where liberal licenses facilitate complex economic organization. The fact that these licenses are "exclusive" has confused some: although they are exclusively *assigned*, flexible use spectrum rights are *not* held as private domains walled off from public encroachment. Just the reverse. Investors bid to gain a platform with which to supply new spectrum sharing technologies to the mass market. Only by making purchased spectrum rights extremely useful to millions of consumers are the prices paid worthwhile – and, looking forward, it is the expectation that such investments will yield net social value that drives the bids observed.

40. It is sometimes asserted that licensed spectrum is largely wasted and that more efficient use of such frequencies can be accomplished by mandating access for unlicensed users employing advanced radios, sharing spectrum under "polite protocols." These arguments are fatally flawed.

41. First, as noted above, although there is a systemic under-utilization problem with respect to airwaves, it is not due to the "licensed" nature of some of

the spectrum. Rather, it largely stems from the large blocks reserved for government use and for traditional restricted-use licenses. These allocations sharply constrict airwave access – the administrative planning approach roundly critiqued by Ronald Coase in 1959 and dubbed "Gosplan" by former FCC Chief Economist Gerald Faulhaber and former FCC Chief Technologist David Farber.[40] It is the truncation of the rights granted in the traditional license that pre-empts efficient transactions from occurring and the most valuable services from being provided.[41]

42. The outcome is that spectrum provides a small portion of its potential value to society. The remedy is to eliminate "Gosplan" by expanding the rights issued in the license, making it a broad grant of authority over specified spectrum space,[42] enabling market reallocation. Licensees are then free to offer innovative services limited only by the prices customers are willing to pay, on the one hand, and the opportunity cost of the inputs consumed, on the other. These constraints guide maximization of social welfare. The gains available increase as the operative margin expands – additional bandwidth for liberal licenses produces large net social benefits.

43. Second, while advanced radio technologies can theoretically be used to supply high-value mobile network (WWAN) services without exclusive rights, they are severely handicapped in doing so. No law explicitly bars service providers from using the unlicensed 900 MHz or 2.4 GHz ISM bands for mobile telephony, where $150 billion in annual revenue is available. The radio spectrum is well suited to the application, as seen in adjacent bands used by wireless phone networks. But the non-exclusive rights in unlicensed spectrum, as well as their regulatory limits, render such bands uneconomical for supplying mobile services.

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[40] Gerald Faulhaber & David J. Farber, "Spectrum Management: Property Rights, Markets, and the Commons," AEI-Brookings Joint Center for Regulatory Studies Working Paper No. 02-12 (Dec. 2002). The FCC has itself used the term "command and control" to describe this spectrum allocation regime. See the FCC Spectrum Policy Task Force Report (2002).

[41] Heller (2008) notes that this results in endemic "tragedy of the anti-commons."

[42] This is extensively discussed in Hazlett (2001, 2005) and Kwerel & Williams (2002). It may be important to note that the interference contours are not precisely defined because – as with all property, contract, or administrative processes – specificity is desired only to the degree that gains outweigh costs. Hazlett, "A Law and Economics Approach to Spectrum Property Rights: A Response to Professors Weiser & Hatfield," 15 *George Mason University Law Review*, No. 3 (June 2008), 975-1023. The bundle of rights issued in the standard CMRS license conveys broad authority to make useful investments and to negotiate interference boundaries, as demonstrated by their productive use in the marketplace.

44. Indeed, unlicensed bands rely on such exclusions to mitigate conflicts. Power limits, in particular, help separate radio users. With liberal licenses, spectrum sharing strategies are delegated to license holders. These parties typically build networks to complement bandwidth and then sell bundled services – spectrum access plus network connectivity. Carriers compete to provide more attractive applications, to expand networks, upgrade connections, and to pack more high-valued traffic into the available frequency space.

45. This is seen, for example, in the relentless upgrading of capacity, both in the quest for new bandwidth (acquiring licenses in primary and secondary markets), and in more intensely "re-using" frequencies via cell splitting and technology upgrades. The effect is shown in Table 3. U.S. mobile carriers increased the number of channels (spaces available for hosting distinct phone calls at any one time) from under three million to over 30 million during the 2000-2008 period. This ten-fold expansion of capacity flows from the carriers' $20 billion per year capex outlays (which does not include spectrum bids). This illustrates carriers' incentives to accommodate new traffic via shared bandwidth.

TABLE 3. TOTAL MOBILE WIRELESS COMMUNICATIONS CHANNELS[43]

Survey Period	Analog Channels	Digital Channels	Total Reported Channels	Total Calculated Channels
December 1992	241,983	873	257,279	242,856
December 1993	294,184	7,591	320,886	301,775
December 1994	388,316	18,123	433,929	406,439
December 1995	527,261	27,836	556,071	555,097
December 1996	666,370	93,879	767,143	760,249
December 1997	762,566	555,772	1,318,917	1,318,338
December 1998	727,003	586,096	1,315,531	1,313,099
December 1999	668,993	2,003,154	2,663,011	2,672,147
December 2000	590,563	3,910,202	4,500,753	4,500,765
December 2001	499,506	6,346,137	6,586,790	6,840,643
December 2002	322,656	7,307,122	7,629,286	7,629,778
December 2003	339,073	13,642,627	13,981,225	13,981,700
December 2004	262,549	13,312,207	13,574,756	13,574,756
December 2005	282,714	20,441,640	20,724,355	20,724,354
December 2006	212,420	20,754,297	26,751,904	20,966,717
December 2007	210,449	28,471,033	28,678,482	28,681,482
December 2008	738	30,096,564	30,097,307	30,097,307

[43] CTIA Year-end Survey (2008), 161.

46. Third, networks using liberal licenses broadly deploy intelligence in base stations and handsets, and use these smart devices to better coordinate spectrum sharing. As RF engineer Charles Jackson notes, "handsets are part of the network."[44] The basic strategy is to reduce less valuable emissions so as to make room for higher valued traffic. One example is the voice compression coding algorithms used in GSM or CDMA networks, "vocoders." These allow the base station to tell handsets to reduce the quality of the voice signals sent, economizing on bandwidth, when the network is congested – perhaps due to a temporary emergency or the loss of an adjacent cell site. Likewise, phones are programmed to turn off their transmitters when listening rather than talking, saving precious bandwidth.[45] In general, networks dynamically adjust power, reducing emissions to the lowest level maintaining a given link. CDMA handsets scroll through the exercise 800 times per second[46]; WCDMA handsets 1500 times.[47]

47. Networks invest heavily to create capacity for the sole purpose of selling it to wireless users – whether it be directly to consumers, to resellers (as in the MVNO model), hardware vendors (as when Sierra Wireless produces wireless broadband modems – dongles -- for a cellular carrier, or Dell produces a netbook with an embedded modem), or to application platform providers such as Apple or RIM (which produce both hardware and software for use with the carrier's spectrum). The scope of such transactions suggests that there is a lively market in selling spectrum access.

48. In evaluating proposals to inject new unlicensed devices into licensed bands, the first question to ask is: why is the additional usage sought via regulation not already accommodated in the market? If the rights held by the licensee will not permit the additional traffic, those rights can be broadened and made more flexible. On the other hand, if the licensee has the rights and elects not to pursue the added traffic, then the outcome reveals that the benefits generated by the additional traffic are not worth its cost.

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[44] Charles L. Jackson, "Wireless Handsets are Part of the Network," CTIA (April 27, 2007); http://files.ctia.org/pdf/Comments_CTIA_SkypeOpposition_AppendixC_43007.pdf.
[45] Jackson (2007), 13-15.
[46] "Spread Betting," *The Economist* (June 21, 2003), 24.
[47] Malcolm W. Oliphant, "Radio Interfaces Make the Difference in 3G Cellular Systems," *IEEE Spectrum*; http://www.spectrum.ieee.org/telecom/wireless/radio-interfaces-make-the-difference-in-3g-cellular-systems/0#.

49. Proponents of additional unlicensed access may respond that such uses today are prevented by transaction costs, but new FCC mandates carry costs of their own. These include not just the administrative expense of developing protocols, but the *opportunity costs imposed by the rules*. Suppose that, in existing cellular bands, unlicensed devices are authorized on a "listen before talk" basis. First, these devices will err in some cases, sending emissions that conflict with network users. No regulatory rule is perfect. Second, when such devices are emitting, the network – detecting such occupancy – will operate with reduced capacity for other uses. Third, with such encroachments, the network's incentive and ability (accessing financial markets) to create new capacity will be diminished; a tax is imposed to the degree that the spectrum use conflicts with network transmissions.

50. The experience of the Commission in the ill-fated Interference Temperature proceeding is telling. There the agency sought to insert unlicensed devices into licensed spectrum, but failed to craft rules that would plausibly increase productivity. Indeed, operating from the premise that no harm would be done by mandating access for unlicensed devices below the noise floor, the Commission was unaware (at least initially) that the noise floor is productively used by technologies deployed by CMRS license holders. Were ad hoc devices to gain access to licensed spaces that operators were attempting to utilize, conflicts were likely.

51. Nor could these conflicts be resolved in the market, because such encroachments would necessarily be undertaken on terms defined by regulators. Only regulators could redraw them. The government rules would crowd out carriers' spectrum sharing efforts – undertaken by powering down handsets, making licensed spectrum quieter, and investing so as to use more and more capacity of the band. This effort to create new capacity would be, on important margins, over-ridden by Commission mandates.

52. After several years, the FCC dropped the rulemaking, stating:

> Commenting parties generally argued that the interference temperature approach is not a workable concept and would result in increased interference in the frequency bands where it would be used. While there was some support in the record for adopting an

interference temperature approach, no parties provided information on specific technical rules that we could adopt to implement it.[48]

53. Policies that facilitate transactions by reducing bargaining costs are potentially worthwhile. Yet there is little evidence that subscribers, radio makers, technology suppliers, application developers, and wireless carriers with liberal licenses are not already engaging in far-reaching, cooperative efforts to make the most of allocated radio spaces. To over-rule this coordination process by imposing FCC mandates is not likely to constitute a pro-consumer policy.

VI. PUBLIC POLICY: THE NEED FOR SPEED

54. Liberal licenses convey spectrum rights that are intensely used and extremely productive. At the relevant policy margin, the net value of additional bandwidth rights issued in such manner is high. New services, including emergent wireless broadband networks, and entrepreneurial application platforms, including "killer apps" like the Blackberry and iPhone, have arisen from the marketplace that such rights enable. Unlicensed bandwidth widely complements, but does not substantially substitute for, these rights. As networks expand and usage grows, the demand for additional bandwidth allocated to liberal licenses is strong.

55. Failing to meet that demand will punish the U.S. economy. The FCC did allocate and auction an additional 90 MHz of valuable spectrum in 2006 and an additional 52 MHz in 2008 – following a long period (from 1997) in which the Commission did little to facilitate carrier access to new bandwidth. During that period, U.S. carriers were constrained with allocations 100-150 MHz below that made available to mobile networks in other countries such as the U.K., France, Germany, and the Netherlands.[49] Now U.S. carriers are building out 3G and 4G networks with the spectrum allotments made recently, but innovative wireless broadband applications are driving consumer demand for still more speed and capacity. If usage-throttling and innovation-deterring price increases are to be avoided, additional frequency space must be available to the market.

56. The cellular industry is actively pressing regulators for new spectrum, a signal that incumbent wireless carriers see bandwidth constraints as severe.

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[48] Federal Communications Commission, *In the Matter of Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands, Order*, 22 FCC Rcd. 8938 (Rel. May 4, 2007), ¶2; http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-07-78A1.pdf (footnotes omitted).

[49] Hazlett & Muñoz (2004).

CTIA sees major EU countries as readying large new allocations, but notes that the FCC has only 50 MHz – AWS2 and AWS3 – in the pipeline. Washington Analysis, an investor information service, lays out a scenario where legislation is required to obtain additional bandwidth.[50] It runs through the time line, assuming policy makers start the process now. When will new bandwidth be available for use? "It will be 2016 – at the earliest."

57. U.S. spectrum policy should relieve this input bottleneck, learning from the well-informed reform process under way in the U.K. since 2002. Led by Martin Cave's excellent analysis of spectrum allocation reform for the British Government,[51] spectrum regulator Ofcom announced a broad liberalization of policy in late 2004. It seeks to turn the great majority of spectrum below 3GHz into liberal license allocations, and appears on track to achieve its goals.[52]

58. It would be foolish for policy makers to extend with one hand what they take away with the other. Mandates that impose new spectrum sharing requirements on competitive carriers utilizing liberal licenses are not likely to produce net benefits, while risking major disincentives for further investments in network capacity. The rivalry among carriers is already driving a burgeoning market in spectrum access, and additional bandwidth will add to the intensity of that development process. To return now to the errors of the Interference Temperature proceeding is to reject the lessons of both history and economics.

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[50] Washington Analysis, "Spectrum Shortage Revisited," Telemedia Update (Sept. 18. 2009).

[51] Martin Cave, "Review of Radio Spectrum Management: An Independent Review for Department of Trade and Industry and HM Treasury" (March 2002); http://www.ofcom.org.uk/static/archive/ra/spectrum-review/2002review/1_whole_job.pdf.

[52] William Webb, "An Optimal Way to License the Radio Spectrum," 33 *Telecommunications Policy* (April-May 2009), 230.

VERIFICATION PAGE

I hereby swear under penalty of perjury that the foregoing is true and correct.

/s/Thomas W. Hazlett
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